Chapter 8.0 National Greenhouse Gas Emissions

8.1 WHAT INFORMATION IS PRESENTED IN THIS CHAPTER?

This chapter summarizes the latest information on anthropogenic greenhouse gas emissions in the United States from 1990 through 1997. For a more detailed discussion, the reader is referred to the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997*, April 1999, United States (U.S.) Environmental Protection Agency (EPA), EPA 236-R-99-003. This report is produced annually and submitted by the U.S. Government to the United Nations as part of our commitments under the Framework Convention on Climate Change (UNFCCC). Readers interested in the international efforts to address the problem of climate change through negotiation are referred to the home page of the UNFCCC at **http://www.unfccc.de**. Readers interested in more background on the science of climate change, global warming or greenhouse gases are referred to the Intergovernmental Panel on Climate Change (IPCC) via their website at **http://www.ipcc.ch**.

To ensure that the U.S. greenhouse gas emissions inventory meets the reporting requirements of the UNFCCC, the estimates were calculated using methodologies consistent with those recommended in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*[1]. For most source categories the IPCC default methodologies were expanded in order to incorporate emission factors and data specific to the United States, resulting in a more comprehensive and detailed estimate of U.S. emissions. (See Section 8.3.3.)

8.2 WHAT ARE THE RECENT TRENDS IN U.S. GREENHOUSE GAS EMISSIONS?

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as halons. Other fluorine containing halogenated substances include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Total U.S. greenhouse gas emissions rose in 1997 to 1,813.6 million metric tons of carbon equivalents (MMTCE). The single year increase in emissions from 1996 to 1997 was 1.3 percent (23.1 MMTCE), down from the previous year's increase of 3.3 percent. Overall, emissions of greenhouse gases have increased 11 percent above 1990 levels. Table 8-1 provides a detailed summary of U.S. greenhouse gas emissions and sinks for 1990 through 1997.

In 1997, the primary greenhouse gas emitted by human activities was CO_2. The largest source of CO_2 and of overall greenhouse gas emissions in the United States was fossil fuel combustion. CH_4 emissions resulted primarily from decomposition of wastes in landfills, manure and enteric fermentation associated with domestic livestock, natural gas systems, and coal mining. Emissions of N_20 were dominated by agricultural soil management and mobile source fossil fuel combustion. The substitution of O_3 depleting substances and emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate HFC emissions. PFC emissions came mainly from primary aluminum production, while electrical transmission and distribution systems emitted the majority of SF_6.

As the largest source of U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion accounted for 81 percent of emissions in 1997 when each gas is weighted by its Global Warming Potential (see Figure 8-1 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1900-1997* for a discussion of global warming potentials). Emissions from fossil fuel combustion grew by 11 percent (138.8 MMTCE) over the 8-year period and were responsible for over three-quarters of the increase in national emissions. The annual increase in CO_2 emissions from this source was 1.3 percent in 1997, down from the previous year when emissions increased by 3.6 percent.

The dramatic increase in fossil fuel combustion related CO_2 emissions in 1996 was primarily a function of two factors: 1) fuel switching by electric utilities from natural gas to more carbon intensive coal as gas prices rose sharply due

to weather conditions, which drove up residential consumption of natural gas for heating; and 2) higher petroleum consumption for transportation. In 1997, by comparison, electric utility natural gas consumption rose to regain much of the previous year's decline as the supply available rose due to lower residential consumption. Despite this increase in natural gas consumption by utilities and relatively stagnant U.S. electricity consumption, coal consumption rose in 1997 to offset the temporary shut-down of several nuclear power plants. Petroleum consumption for transportation activities in 1997 also grew by less than a percent, compared to almost 4 percent the previous year (see Table 8-2).

Overall, from 1990 to 1997, total emissions of CO_2, CH_4, and N_2O increased by 143.5 (11 percent), 9.7 (6 percent), and 13.4 MMTCE (14 percent), respectively. During the same period, weighted emissions of HFCs, PFCs, and SF_6 rose by 14.9 MMTCE (67 percent). Despite being emitted in smaller quantities, emissions of HFCs, PFCs, and SF_6 are significant because of their extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, which was estimated to be 11 percent of total emissions.

Other significant trends in emissions from other source categories over the 8-year period of 1990 through 1997 included:

- Aggregate HFC and PFC emissions resulting from the substitution of ozone depleting substances (e.g., CFCs) increased dramatically (by 14.4 MMTCE). This increase was partly offset, however, by reductions in PFC emissions from aluminum production (41 percent) and HFC emissions from HCFC-22 production (14 percent), both as a result of voluntary industry emission reduction efforts and, in the former case, from falling domestic aluminum production.

- Combined N_2O and CH_4 emissions from mobile source fossil fuel combustion rose 3.9 MMTCE (26 percent), primarily due to increased rates of N_2O generation in highway vehicles.

- CH_4 emissions from the decomposition of waste in municipal and industrial landfills rose by 10.5 MMTCE (19 percent) as the amount of organic matter in landfills steadily accumulated.

- Emissions from coal mining dropped by 5.2 MMTCE (21 percent) as the use of CH_4 from degasification systems increased significantly.

- N_2O emissions from agricultural soil management increased by 8.8 MMTCE (13 percent) as fertilizer consumption and cultivation of nitrogen fixing crops rose.

- An additional domestic adipic acid plant installed emission control systems in 1997, which was estimated to have resulted in a 1.4 MMTCE (27 percent) decline in emissions from 1996 to 1997 despite an increase in production.

8.3 WAS A MORE DETAILED ANALYSIS OF INDUSTRIAL EMISSIONS CONDUCTED?

Yes. An analysis of the industrial sector was conducted to provide greater resolution on the greenhouse gas emissions and energy consumption trends in the industrial end-use sector.

Figures 8-1 through 8-3 present CO_2 emissions data by industry end-use sector for the entire United States in the year 1994.

8.3.1 What Data Were Used in this Analysis?

This analysis was based on data contained in several EPA and Energy Information Administration (EIA) reports: the Manufacturing Consumption of Energy 1994, DOE/EIA-0512(94);[2] The Annual Energy Review 1997, DOE/EIA-0384(97);[3] Emissions of Greenhouse Gases in the United States 1997, DOE/EIA-0573(97);[4] and the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996, EPA 236-R-98-006.[5]

The Annual Energy Review, EIA and the Emissions of Greenhouse Gases, EPA were used to develop national estimates of CO_2 for the year 1994. Both of these inventories report data on CO_2 emissions caused by both fuel combustion and industrial processes, and both were included in this analysis. Typically, fossil fuel combustion represents 81 percent of total U.S. greenhouse gas emissions and 99 percent of total U.S. CO_2 emissions, although there is some year-to-year variance. Cement manufacture is the largest remaining source of industrial CO_2 emissions, and has been estimated to contribute about 10 MMTCE to annual U.S. emissions. For more information on industrial sources of CO_2 or other greenhouse gas emission data, the reader is referred to the EPA inventory document or web site at **www.epa.gov/globalwarming/inventory**.

The Manufacturing Consumption of Energy (MECS) data were used to develop the detailed estimates for the industry sector. The MECS data are prepared once every 4 years, thus 1994 is presented as the most recent year for which the MECS data are available. The MECS data contain rich detail on manufacturing industries, but no information on the non-manufacturing industries, such as agricultural activity, mining, and construction. The MECS data were

merged with estimates of total industrial energy use to develop these results. Emission estimates were developed using carbon coefficients for various fuel types, and for a quality assurance check, were compared with national inventory data. Refer to Annex A of the EPA Inventory document for more detail on carbon coefficients for fuel types. Table 8-3 presents the actual carbon coefficients used in this analysis.

8.3.2 What are the Results?

The results of this analysis show that the majority of CO_2 emissions can be attributed to a few major end-use sectors.

The utility sector, which represents 36 percent of total CO_2 emissions in 1994, supplies energy to industry. Emissions resulting from electricity production can thus be prorated to industry on the basis of electricity consumption. Ideally, this would be done on a regional basis in order to best capture the complexity of our nation's energy supply system and to account for variations in carbon emissions per kilowatt hour. However, this analysis uses national averages to develop the carbon emissions embedded in electricity consumption and attributes these emissions to the industries on the basis of their electricity demand.

Figure 8.1 shows total U.S. CO_2 emissions in 1994. Utilities contribute 36 percent of that total, with transportation the second largest sector at 30 percent of total CO_2 emissions. Emissions from utilities were estimated at 492 MMTCE in 1994, with 87 percent of that total resulting from coal consumption, 9 percent from natural gas, and 4 percent from petroleum fuel consumption.

Figure 8.2 presents all industrial emissions of CO_2 - both manufacturing and non-manufacturing - and the graph was developed to account for both "on-site" and "off-site" emissions. In this case, on-site emissions are process-related emissions such as CO_2 flux from lime calcination, and off-site emissions refer to the emissions that result from fossil fuel consumption at power plants supplying electricity to industry.

Figure 8.3 presents CO_2 emissions for the entire United States, and differs from Figure 8.1 in that utility sector has been "mapped" into the various end-use sectors that consume the electricity generated at utilities. Table 8.4 presents the CO_2 emissions data in tabular form.

8.3.3 What Methodologies were Utilized?

Emissions of greenhouse gases from various sources have been estimated using methodologies that are consistent with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*.[1] To the extent possible, the present U.S. inventory relies on published activity and emission factor data. Depending on the emission source category, *activity data* can include fuel consumption or deliveries, vehicle-miles traveled, raw material processed, etc.; *emission factors* are factors that relate quantities of emissions to an activity. For some sources, IPCC default methodologies and emission factors have been employed. However, for emission sources considered to be significant sources in the United States, the IPCC default methodologies were expanded and more comprehensive methods were applied. The Annexes of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997* contain additional detail and documentation on the calculations and assumptions used to obtain these estimates. This report can be found online at **www.epa.gov/globalwarming/inventory**.

Inventory emission estimates from energy consumption and production activities are based primarily on the latest official fuel consumption data from the EIA/DOE. CO_2 emissions from fuel combusted in ships or aircraft engaged in the international transport of passengers or cargo are not included in U.S. totals, but are reported separately as international bunkers in accordance with IPCC reporting guidelines.[1] CO_2 emissions from fuel combusted within U.S. territories, however, are included in U.S. totals.

Data on fuel consumption for the United States and its territories, carbon content of fuels, and percent of carbon sequestered in non-energy uses were obtained directly from the EIA/DOE. Fuel consumption data were obtained primarily from the *Monthly Energy Review*[6] and various EIA databases. U.S. marine bunker fuel consumption data for distillate and residual fuel oil was taken from *Fuel Oil and Kerosene Sales*.[7] Marine bunker fuel consumption in U.S. territories was collected from internal EIA databases[8] used to prepare the *International Energy Annual*.[9] Jet fuel consumption for aviation international bunkers was taken from *Fuel Cost and Consumption*,[10] which are monthly data releases by the Department of Transportation's Bureau of Transportation Statistics (DOT/BTS), and unpublished data from the Bureau of Economic Analysis (BEA).[11] The data collected by DOT/BTS includes fuel consumed for international commercial flights both originating and terminating in the United States. One-half of this value was assumed to have been purchased in the United States.[a]

IPCC[1] provided combustion efficiency rates for petroleum and natural gas. Bechtel[11] provided the combustion efficiency rates for coal. Vehicle type fuel consumption data for the allocation of transportation sector emissions were primarily taken from the *Transportation Energy Databook*[12] prepared by the Center for Transportation Analysis at Oak Ridge National Laboratory (DOE 1993, 1994, 1995, 1996, 1997, 1998). All jet fuel and aviation gasoline were assumed to have been consumed in aircraft.

8.4 REFERENCES

1. "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories," Paris: Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Co-Operation and Development, International Energy Agency. 1997.
2. "Manufacturing Consumption of Energy 1994," DOE/EIA-0512(94), Energy Information Administration, U.S. Department of Energy, Washingotn, DC. 1994.
3. "Annual Energy Review 1997," DOE/EIA- 0384(97)-annual, Energy Information Administration, U.S. Department of Energy, Washington, DC. July 1998.
4. "Emissions of Greenhouse Gases in the United States 1997," DOE/EIA-0573(97), Energy Information Administration, U.S. Department of Energy, Washington, DC. 1997.
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6. "Monthly Energy Review," DOE/EIA- 0035(98)-monthly, Energy Information Administration, U.S. Department of Energy, Washington, DC. July 1998.
7. "Fuel Oil and Kerosene Sales 1997," DOE/EIA-0535(97)-annual, Energy Information Administration, U.S. Department of Energy, Washington, DC. 1998.
8. "Report of Bunker Fuel Oil Laden on Vessels Cleared for Foreign Countries," unpublished, Form-563, Foreign Trade Division, Bureau of the Census, U.S. Department of Commerce. 1998.
9. "International Energy Annual 1996," DOE/EIA-0219(96)-annual, Energy Information Administration, U.S. Department of Energy, Washington, DC. 1998.
10. "Fuel Cost and Consumption," monthly reports, DAI-10, Federal Aviation Administration, U.S. BTS, Department of Transportation, Washington, DC. 1998.
11. "Survey of Current Business," Bureau of Economic Analysis, Department of Commerce, Table 2A, p. 152, August 1998. **http://www.bea.doc.gov/bea.dn1.htm**
12. DOE (1993-1998) "Transportation Energy Databook," (1993-1998), prepared by the Center for Transportation Analysis at Oak Ridge National Laboratory for the Department of Energy, Oak Ridge, IL.

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a. See section titled International Bunker Fuels for a more detailed discussion.

Table 8-1. Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMTCE)

Gas/Source	1990	1991	1992	1993	1994	1995	1996	1997
CO_2	**1,344.3**	**1,329.8**	**1,349.6**	**1,379.2**	**1,403.5**	**1,419.2**	**1,469.3**	**1,487.9**
Fossil Fuel Combustion	1,327.2	1,312.6	1,332.4	1,360.6	1,383.9	1,397.8	1,447.7	1,466.0
Natural Gas Flaring	2.3	2.6	2.6	3.5	3.6	4.5	4.3	4.2
Cement Manufacture	8.9	8.7	8.8	9.3	9.6	9.9	9.9	10.2
Lime Manufacture	3.3	3.2	3.3	3.4	3.5	3.7	3.8	3.9
Limestone and Dolomite Use	1.4	1.3	1.2	1.1	1.5	1.9	2.0	2.1
Soda Ash Manufacture and Consumption	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2
Carbon Dioxide Consumption	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Land-Use Change and Forestry (Sink)[a]	(311.5)	(311.5)	(311.5)	(208.6)	(208.6)	(208.6)	(208.6)	(208.6)
International Bunker Fuels[b]	27.1	27.8	29.0	29.9	27.4	25.4	25.4	26.6
CH_4	**169.9**	**171.0**	**172.5**	**172.0**	**175.5**	**178.6**	**178.3**	**179.6**
Stationary Sources	2.3	2.4	2.4	2.4	2.4	2.5	2.5	2.2
Mobile Sources	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Coal Mining	24.0	22.8	22.0	19.2	19.4	20.3	18.9	18.8
Natural Gas Systems	32.9	33.3	33.9	34.1	33.5	33.2	33.7	33.5
Petroleum Systems	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.6
Petrochemical Production	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Silicon Carbide Production	+	+	+	+	+	+	+	+
Enteric Fermentation	32.7	32.8	33.2	33.6	34.5	34.9	34.5	34.1
Manure Management	14.9	15.4	16.0	16.1	16.7	16.9	16.6	17.0
Rice Cultivation	2.5	2.5	2.8	2.5	3.0	2.8	2.5	2.7
Agricultural Residue Burning	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Landfills	56.2	57.6	57.8	59.7	61.6	63.6	65.1	66.7
Wastewater Treatment	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
International Bunker Fuels[b]	+	+	+	+	+	+	+	+
N_2O	**95.7**	**97.6**	**100.1**	**100.4**	**108.3**	**105.4**	**108.2**	**109.0**
Stationary Sources	3.8	3.8	3.9	3.9	4.0	4.0	4.1	4.1
Mobile Sources	13.6	14.2	15.2	15.9	16.7	17.0	17.4	17.5
Adipic Acid	4.7	4.9	4.6	4.9	5.2	5.2	5.4	3.9
Nitric Acid	3.3	3.3	3.4	3.5	3.7	3.7	3.9	3.8
Manure Management	2.6	2.8	2.8	2.9	2.9	2.9	3.0	3.0
Agricultural Soil Management	65.3	66.2	68.0	67.0	73.4	70.2	72.0	74.1
Agricultural Residue Burning	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Human Sewage	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.3
Waste Combustion	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
International Bunker Fuels[b]	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2
HFCs, PFCs, and SF_6	**22.2**	**21.6**	**23.0**	**23.4**	**25.9**	**30.8**	**34.7**	**37.1**
Substitution of Ozone Depleting Substances	0.3	0.2	0.4	1.4	4.0	9.5	11.9	14.7
Aluminum Production	4.9	4.7	4.1	3.5	2.8	2.7	2.9	2.9
HCFC-22 Production	9.5	8.4	9.5	8.7	8.6	7.4	8.5	8.2
Semiconductor Manufacture	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.3
Electrical Transmission and Distribution	5.6	5.9	6.2	6.4	6.7	7.0	7.0	7.0
Magnesium Production and Processing	1.7	2.0	2.2	2.5	2.7	3.0	3.0	3.0
Total Emissions	**1,632.1**	**1,620.0**	**1,645.2**	**1,675.0**	**1,713.2**	**1,733.9**	**1,790.5**	**1,813.6**
Net Emissions (Sources and Sinks)	**1,320.6**	**1,308.5**	**1,333.7**	**1,466.5**	**1,504.7**	**1,525.4**	**1,582.0**	**1,605.0**

+ Does not exceed 0.05 MMTCE

[a] Sinks are only included in net emissions total. Estimates of net carbon sequestration due to land-use change and forestry activities exclude non-forest soils, and are based partially upon projections of forest carbon stocks.

[b] Emissions from International Bunker Fuels are not included in totals.

Note: Totals may not sum due to independent rounding.

Table 8-2. Annual Percent Change in CO_2 Emissions from Fossil Fuel Combustion for Selected Sectors and Fuels

Sector	Fuel Type	1995 to 1996	1996 to 1997
Electric Utility	Coal	5.7%	2.9%
Electric Utility	Natural Gas	-14.6%	8.7%
Residential	Natural Gas	8.1%	-4.4%
Transportation*	Petroleum	3.4%	0.3%

* Excludes emissions from International Bunker Fuels

Table 8-3. Carbon Coefficients, MMTCE/QBtu (Q=E15)

Year	Electricity	Residual Oil	Distillate Oil	NG	LPG	Coal	Coke	Still Gas
1994	50	21.49	19.95	14	17.01	25	25	20.19
1995	50	21.49	19.95	14	16.99	25	25	20.23

Table 8-4. Carbon Dioxide Emissions in the U.S., 1994 (MMTCE)

Sector/Source Category	Electricity	Petroleum	NG	Coal	Still Gas, Coke, Other	Process CO_2	Total	% of Industrial CO_2 Emissions	% of Total CO_2 Emissions	% of Total Greenhouse Gas Emissions
Agriculture	9.6	14.0	0.0	0.0	0.0	0.0	23.6	5%	2%	1%
Mining & construction	17.2	15.4	42.8	13.4	0.0	0.0	88.7	18%	6%	5%
Food Products	9.9	1.1	8.8	4.1	2.7	0.0	26.6	5%	2%	2%
Tobacco Products	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0%	0%	0%
Textile Products	5.6	0.4	1.6	1.0	0.3	0.0	9.1	2%	1%	1%
Apparel	1.3	0.0	0.3	0.0	0.0	0.0	1.8	0%	0%	0%
Lumber & wood	3.4	0.4	0.7	0.0	1.2	0.0	5.9	1%	0%	0%
Furniture & fixtures	1.1	0.0	0.3	0.1	0.3	0.0	1.8	0%	0%	0%
Paper	11.2	3.9	8.0	7.6	0.0	0.0	30.7	6%	2%	2%
Printing	3.0	0.0	0.7	0.0	0.0	0.0	3.8	1%	0%	0%
Chemicals	30.1	1.5	26.4	6.4	8.8	0.0	73.3	15%	5%	4%
Petroleum-Refining	10.2	2.7	0.0	0.0	41.9	0.0	73.3	15%	5%	4%
Rubber	7.5	0.3	1.5	0.1	0.1	0.0	9.5	2%	1%	1%
Leather	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0%	0%	0%
Stone, clay & glass	6.2	0.7	6.0	6.8	1.7	16.0	37.3	8%	3%	2%
Primary metal	28.8	1.2	11.2	1.3	24.8	0.0	67.3	14%	5%	4%
Fabricated metal	5.8	0.2	3.1	0.0	0.0	0.0	9.5	2%	1%	1%
Industrial machinery	5.5	0.1	1.5	0.3	0.1	0.0	7.6	2%	1%	0%
Electronic equip	5.7	0.1	1.2	0.0	0.0	0.0	7.8	2%	1%	0%
Transportation equip	6.6	0.4	2.1	0.7	0.4	0.0	10.4	2%	1%	1%
Instruments	2.3	0.1	0.0	0.6	0.0	0.0	4.3	1%	0%	0%
Misc manufacturing	1.0	0.0	0.3	0.0	0.0	0.0	1.6	0%	0%	0%
Industry Total	172.0	43.4	128.3	43.1	83.4	16.0	486.2	102%	35%	28%
Transportation	0.0	411.2	10.2	0.0	0.0	0.0	422.1		30%	25%
Commercial	153.0	14.9	42.9	2.1	0.0	0.0	214.1		15%	12%
Residential	166.9	25.3	71.8	1.4	0.0	0.0	268.6		19%	16%
Territories	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0%	0%
Total	491.9	506.0	253.2	46.6	83.4	16.0	1405.0		100%	82%

Figure 8-1. U.S. Carbon Dioxide Emissions by Sector (1994)

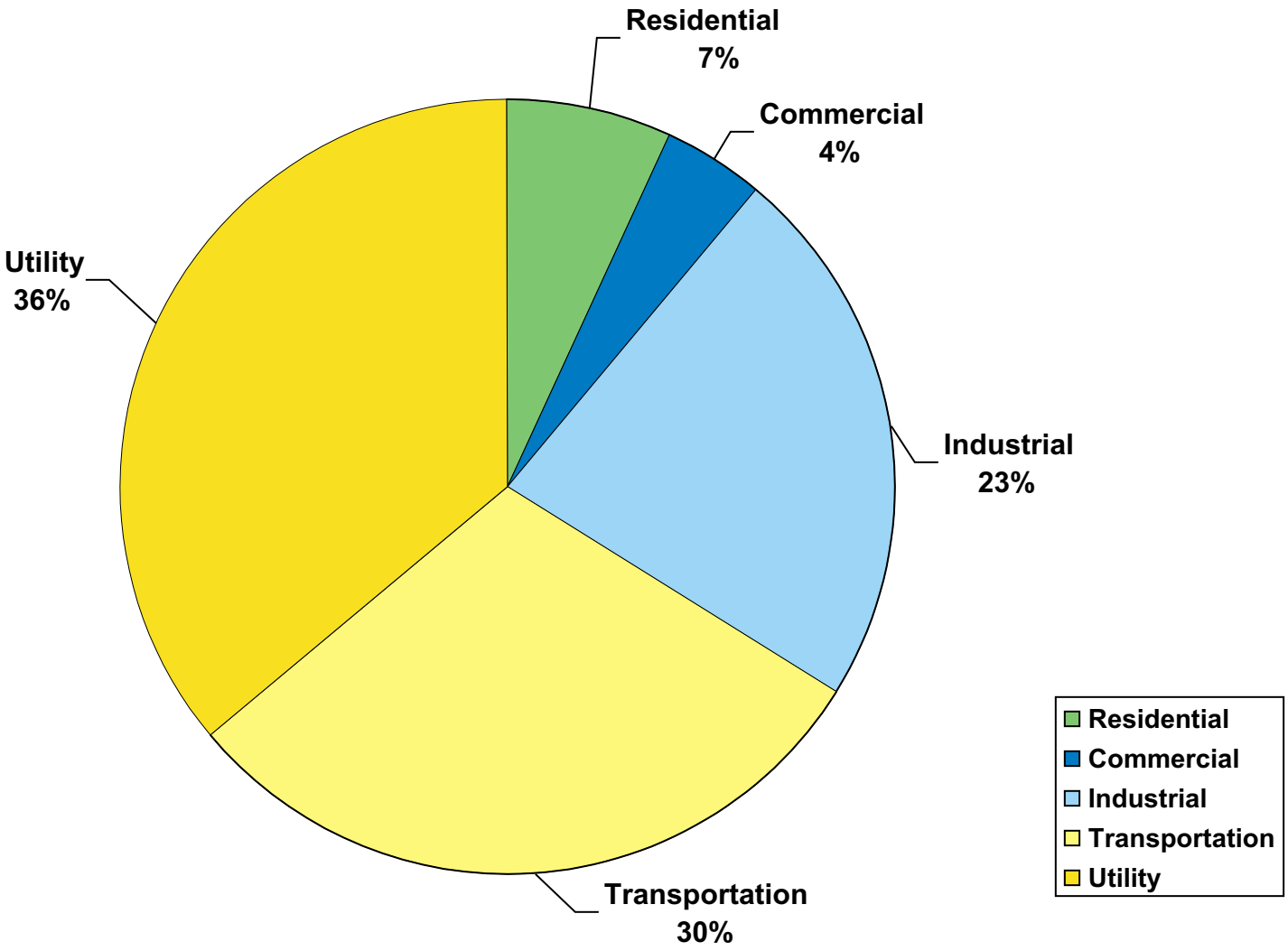

Figure 8-2. Carbon Dioxide Emissions from Industry (1994)

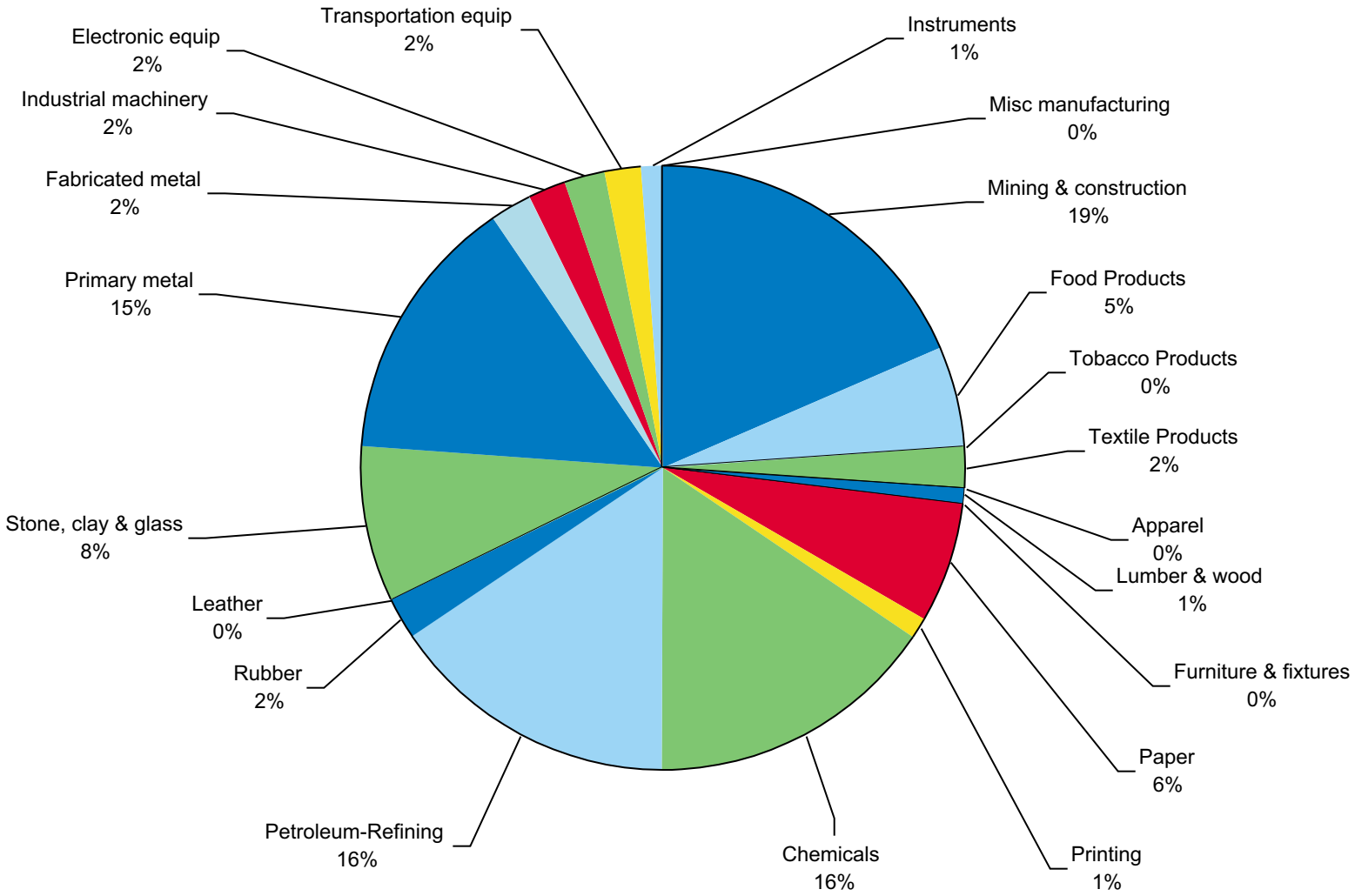

Figure 8-3. U.S. Carbon Dioxide Emissions by End-Use Sector in 1994